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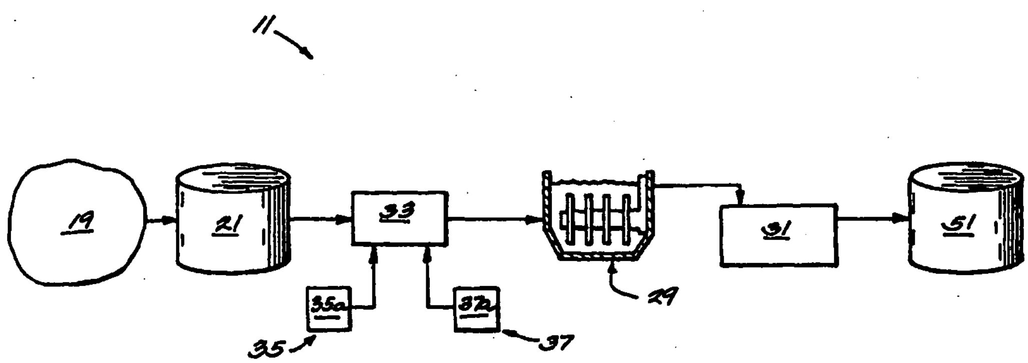

(57) Abstract

In a process for treating water to produce potable water fit for human consumption, a treatment method is employed for reducing the concentration of pathogenic microorganisms in a volume of water (19) that contains pathogenic microorganisms less than about 10 microns in size. The process includes s primary treatment facility (21), adding an agglomerate-promoting agent (35, 37) such as a coagulant chemical to the volume of water such that solids aggregates form in an agglomeration vessel (33), passing the water through a filter cloth membrane (29) to separate greater than about 50.0 % of the pathogenic microorganisms, and disinfecting in a disinfection facility (31). The filter cloth membrane used is constructed of random web needled polyester felt.

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POTABLE WATER SYSTEM AND PROCESS

BACKGROUND OF THE INVENTION

The present invention relates generally to a process for treating water to produce potable water fit for human consumption and, more particularly, to a process for removing microbial contaminants, including pathogenic microorganisms, suspended in the influent water.

When ingested, pathogenic microorganisms can cause such diseases as dysentery, cholera, typhoid, and gastroenteritis. Substantial concentrations of water-borne pathogenic microorganisms are found in sewage outlets, wildlife watersheds, farm lots, garbage dumps, and septic tank systems. The migration of pathogenic microorganisms from these sources into drinking water supplies, i.e. lakes, rivers, and reservoirs, can lead to major health problems for local communities and is a serious problem in both developed and developing countries throughout the world.

Most pathogenic microorganisms can be classified as protozoan, bacteria, and viruses. The viruses of particular concern to potable water treatment are water-borne polio viruses and rota viruses.. Bacteria comprise the largest group of pathogenic microorganisms and include *Salmonella*, *Shigella*, *Escherichia coli*, and a broad variety of others generally known. The most common bacteriological diseases include shigellosis, which causes dysentery, food poisoning, and cholera. Protozoan pathogens include *Giardia sp.* which causes giardiasis, one of the most prevalent water-borne disease in the United States, and *Cryptosporidium sp.*, which causes dysentery.

Water quality standards have long been established in the United States by federal agencies, and, more recently through state and federal laws. To meet these standards, a variety of treatment techniques are employed. For example, water supplies may be contained in storage reservoirs prior to distribution to allow

some pathogenic microorganisms to die naturally. Water supplies may also be disinfected by chlorination. Chlorination provides the added benefit of leaving chlorine residue in the treated water. This chlorine is carried with the potable water during distribution and prevents recontamination of the water. It is believed, however, that the introduction of high levels of chlorine into the distribution system may have some adverse side effects. While chlorination may be generally effective against bacteria and viruses, it is generally less effective against protozoans. Disinfecting by ozonation, on the other hand, is generally more effective against some viruses and protozoans but not as effective against most bacteria. Ozonation is also relatively expensive.

Filtration techniques have been used to reduce the concentrations of pathogenic microorganisms in some potable water treatment processes. More specifically, granular media type filters such as deep-bed sand filters are used to strain out fine particles prior to chlorination. The rate or degree at which these filters can separate pathogenic microorganisms from a liquid stream varies with respect to the type of pathogenic microorganisms in the stream and, more particularly, to the size of the microorganisms. While most bacteria are about 10 microns or less in size, most protozoans are less than 5 microns and most viruses are less than 0.1 microns. The use of granular media type filters is more effective in removing some larger particles from liquid streams than in removing small particles such as viruses. In any event, it is alleged that filtration using deep bed multi-media filters can reduce the concentration of viruses and bacteria in a given volume of water by 30% to 40%.

SUMMARY OF THE INVENTION

It is a principal object of the present invention to provide a method that employs an improved filtration technique to reduce the concentration of suspended microbial contaminants, including pathogenic microorganisms, in a volume of water above the 30% to 40% reduction or removal rate that is achievable with prior art methods which employ filters. It is a further object of the invention to provide such a method that is particularly adapted in the treatment of influent water to produce potable water fit for human consumption.

The method according to the invention includes providing a reference volume of influent water that contains suspended microbial contaminants (e.g., including pathogenic microorganisms), and then, promoting the agglomeration of suspended solids in the influent water to form suspended solids aggregates which include microbial contaminants. Agglomeration of solids aggregates may be promoted by adding an agglomerate-promoting agent such as a coagulant and/or a flocculant to the volume of influent water. The influent water including the solids aggregates is then passed through a filter membrane or filter media, thereby separating microbial contaminants from the influent water. The filter membrane may be constructed from a cloth material, preferably needled polyester felt having a random web construction and characterized by an average free passage through the filter membrane (or flow through size) of greater than about 5 microns.

In one aspect of the invention, the step of passing the volume of influent water, including the solids aggregates, through the filter membrane separates greater than about 50% of the microbial contaminants (e.g., pathogenic microorganisms) from the reference volume of influent water. The influent water may also contain microbial contaminants that are less than about 10 microns (e.g., protozoan, bacteria,

and/or viruses) or less than about 5 microns in size (e.g., protozoan and/or viruses). In an unexpected manner, the step of passing the volume of influent water through the filter membrane has been found to separate greater than about 50%, and up to greater than about 99.9%, of such microbial contaminants from the reference volume of influent water.

Further, the reference volume of influent water may contain microbial contaminants less than about 0.1 microns in size including, but not limited to, viruses. In an unexpected manner, the step of passing the volume of influent water through the filter membrane has been found to separate greater than about 50%, and up to greater than about 99%, of such microbial contaminants from the reference volume of influent water.

Before embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of the apparatus, composition or concentration of components, or to the steps or acts set forth in the following description. The invention is capable of other embodiments and of being practiced or being carried out in various ways. Also, it is understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic of a potable water treatment system capable of employing a treatment method according to the invention.

FIG. 2 is a side view of a filter apparatus in the potable water treatment system.

FIG. 3 is a front view of the filter apparatus.

FIG. 4 is a cross-sectional view through a filter disk of the filter apparatus.

DETAILED DESCRIPTION

The treatment method according to the invention is particularly adapted to the treatment of influent water containing microbial contaminants including pathogenic and non-pathogenic microorganisms less than about 30 microns in size. In one aspect of the invention, the method is employed to separate or remove from the influent water, microbial contaminants that are less than about 10 microns in size (e.g., most bacteria, protozoans, and viruses) and/or less than about 5 microns in size (e.g., protozoan pathogens such as Cryptosporidium sp. and giardia, and viruses). In another aspect of the invention, the method is employed to separate microbial contaminants that are less than about 0.1 microns in size (e.g., viruses).

FIG. 1 illustrates a basic potable water treatment system 11 that can employ a treatment method according to the invention. Although the system shown and discussed below operates in a continuous manner, it should be understood that this system, or other systems embodying the invention, may operate in a batch mode.

Raw water supply 19 is typically drawn from a lake, river, or other body of water, and then stored in a storage tank, basin, or reservoir 21. In addition to larger solid particles, the raw water contains a significant amount of very fine particles which are suspended or dissolved in the water, and which include microbial contaminants less than about 30 microns in size. The microbial contaminants include pathogenic microorganisms less than 10 microns in size such as protozoan, bacteria, viruses, and some parasites. While some pathogenic microorganisms die within two days to two weeks in the water, a significant amount remain in the raw water contained in the storage reservoir 21 or is drawn therefrom prior to dying.

The potable water treatment system 11 includes an agglomeration contactor or vessel 33 that is fluidly connected on an inlet side with the storage reservoir

25, and also with a first chemical addition system 35 and a second chemical addition system 37. The agglomeration vessel 33 is positioned between the storage reservoir 25 and a filter apparatus 29, and can accommodate the flow or transfer of water from the storage reservoir 25 to the filter apparatus 29. In the agglomeration vessel 33, generally known methods are employed to promote the agglomeration of suspended solids in the water to form suspended solids aggregates that include microbial contaminants. As will be shown below, the effectiveness of the filter apparatus 29 to remove such suspended solids and other microbial contaminants is enhanced by promoting the agglomeration of solids prior to filtering. It should be noted, however, that the structure of the agglomeration vessel 33 is partly dependent upon the method of agglomeration employed.

In a preferred method of the invention, filter-aid agents are added to the water as it is passed through the agglomeration vessel 33. The agglomeration vessel 33 illustrated in FIG. 1 is an elongated mixing basin 33 that is separately fluidly connected to the first and second chemical addition systems 35, 37. As will be recognized by one skilled in the art, most known chemical addition systems will be workable in the current system as long as such systems are capable of adding filter-aid agents to the water in the agglomeration vessel 33, 25 as needed (and when needed) to promote formation of the solids aggregates. For example, the agglomeration vessel 33 may, in the alternative, be a section of conduit positioned between the storage reservoir 25 and the filter apparatus 29 through which the water flows and into which filter-aid agents are added. Other structures generally known in the art may also be used. Further, the addition of filter-aid agents into the agglomeration vessel 33 may occur in a one step, or multi-step process, and may

occur by manual or by automated methods generally known.

FIG. 1 illustrates automated chemical addition systems 35, 37, each of which includes a reservoir 35a, 37a for retaining a supply of a filter-aid agent. Each chemical addition system 35, 37 also includes a conduit interconnecting the reservoir 35a, 37a with the agglomeration vessel 33, and a pump (not shown) for selectively transferring amounts of filter-aid agents into the agglomeration vessel 33. Each reservoir 35a, 37a may also include a static mixer (not shown) for producing a generally homogeneous mixture of filter-aid agent, and for facilitating the preparation of a filter-aid agent.

The filter-aid agents are preferably agglomeration-promoting agents such as coagulants, flocculants, or other chemicals or mixtures generally known. When added to the water in the proper amounts, such agents bring small suspended solid or semi-solid particles together to form clumps or masses of larger particles that are more effectively removed by filtration. Preferred filter-aid agents include coagulants, flocculants, solutions or mixtures containing coagulants or flocculants, and mixtures thereof that are generally known for use in the agglomeration of suspended solids in the water. The terms coagulation and flocculation, and likewise coagulant and flocculant, are often used interchangeably, but may be better understood if seen as two different mechanisms. Coagulants are chemicals which de-stabilize the solids suspended in colloidal suspension by neutralizing the repulsive forces that keep the solids apart and allow the suspended solids to group together. Flocculants, on the other hand, are chemicals which physically bridge between the suspended solids to help form larger filterable flocs (i.e., solids aggregates). Many coagulants known for use in water treatment systems can perform both coagulant and

flocculant functions by neutralizing surface charges, and adsorbing onto more than one colloid to form a bridge between them.

Most known coagulants for use in water treatment and which are not detrimental to the filtration process are usable in the present invention. In particular, coagulants usable in the present invention include, but are not limited to, inorganic coagulants, such as metal coagulants including aluminum salts, iron salts such as aluminum sulfate (alum), activated silica, and bentonite. Other usable coagulants include indifferent electrolytes, such as sodium chloride, and organic polyelectrolytes, preferably cationic polyelectrolytes. Examples of cationic polyelectrolyte coagulants include, but are not limited to: polyethyleneamine, quaternized polyamines, epichlorohydrine-dimethylamine, diallydimethylaminonium chloride, polyethylene imine, and polyalkalene polyamine.

Most flocculants known for use in water treatment are usable in the current invention as long as they are not detrimental to the filtration process.
Usable flocculants include, but are not limited to, aluminum sulfate, lime, ferric chloride, and other iron salts, polyelectrolytes, and mixtures thereof. Usable flocculants also include, but are not limited to, organic polymers such as cationic polyelectrolytes, anionic polyelectrolytes, and non-ionic polymers. Examples of usable cationic polyelectrolytes include, but are not limited to, acrylamide/diallyldimethy-ammonium chloride copolymer, acrylamide/amine copolymer, and Mannich polymer. Examples of usable non-ionic polyectrolytes include, but are not limited to, polyacrylyamide and polyethylene oxide. Examples of anionic polymers include hydrolyzed polyacrylamide and acrylamide/acrylate copolymer.

Generally, the amount of filter-aid agents added to the water is dependent upon many factors including: the type of filter-aid agent used, the general water

chemistry, the amount of total suspended solids in the water, the flow rate of the water through the agglomeration vessel 33, and other factors appreciated by those skilled in the art. Agglomeration of suspended solids in water using coagulants and flocculants is generally known by those skilled in the art, and known methods and dosages of adding coagulants and flocculants to the water are usable in the current invention.

In a preferred process of the invention as illustrated in FIG. 1, two distinct filter-aid agents or mixtures of filter-aid agents are added to the water in the agglomeration vessel 33: a first filter-aid agent that acts primarily as a coagulant, and a second filter-aid agent that acts primarily as a flocculant. The first filter-aid agent is added to the agglomeration vessel 33 by the first chemical addition system 35, and the second filter aid agent is added to the agglomeration vessel 33 by the second chemical addition system 37. In a more preferred embodiment, the first filter-aid agent is granular aluminum sulfate (alum). The alum is preferably put into an aqueous mixture for ease of addition into the wastewater. The first filter-aid solution is preferably added to the agglomeration vessel 33 such that it is present in a concentration of between about 2 mg and about 10 mg (2 to 10 ppm) per liter of water flowing through the agglomeration vessel 33, and more preferably about 10 mg/L of water (10 ppm). The second filter-aid chemical is preferably an organic polymer flocculants such as a mixture commercially available under the trademark Cytec Superfloc A-130. The second filter-aid chemical is preferably put into an aqueous mixture for ease of addition into the water. The second filter-aid agent is added to the agglomeration vessel 33 at a rate such that between about 0.5 mg and about 3 mg (0.5 to 3 ppm) of the second filter-aid agent is added per liter of

water flowing through the agglomeration vessel 33, and more preferably about 1 mg/L (1 ppm).

In adding the filter-aid agents to the agglomeration vessel 33, it is advantageous to thoroughly mix the filter-aid agents with the water. In this regard, it may be advantageous to use a mixing apparatus in the agglomeration vessel 33, such as a static mixer, a turbine or propeller type impeller, or the like. Preferably, the agglomeration vessel 33 is a complete mixing basin or a reaction basin having close to an ideal plug flow or constant flow. Moreover, the contact time or residence time of each of the filter-aid agents with the water in the agglomeration vessel 33 should be sufficient to allow for the desired agglomeration effect. In a preferred embodiment, the average contact time of the coagulant is about 0.5 to about 3 minutes (preferably about 2 minutes), and the average contact time of the flocculant is between about 0.5 to about 2 minutes (preferably about 1 minute).

The potable water treatment system 11 further includes one or more filter apparatus 29 through which water from the agglomeration vessel 33 may be passed to separate or remove the solids aggregates and other fine particles from the water stream. Referring to FIGS. 2 and 3, the filter apparatus 29 may include a filter tank 113 having an influent inlet 115 and an effluent outlet 117, and a plurality of rotatable filter disks 119 disposed between the influent inlet 115 and the effluent outlet 117. Each of the filter disks 119 supports a filter media, membrane or material 121 through which the water is passed. The filter apparatus 29 depicted in FIGS. 2 and 3 includes four filter disks 119, but the filter tank 113 may be sized, in alternative embodiments, to hold more than four filter disks 119 or fewer filter disks 119, depending on the particular filtering demand of the potable water treatment process.

Referring to FIG. 2, the filter disks 119 are generally vertically disposed and spaced apart in parallel relation. The filter disks 119 are supported by, and fixed to, a horizontally disposed hollow drum 125 that is supported for rotation about its central longitudinal axis by a mounting assembly 123. The mounting assembly 123 is comprised of at least three rollers 127 which engage an outer surface of the hollow drum 125 and allow the hollow drum 125 and the filter disks 119 to be rotated about a horizontal central longitudinal axis of the drum 125. A sprocket 131 encircles the hollow drum 125, and a chain drive 133 drivingly engages the sprocket 131. The chain drive 133 is adapted to be driven by a motor assembly 137 for rotating the hollow drum 125 and filter disks 119.

The filter tank 113 is formed by a hoppered bottom 143, upwardly extending side walls 145, and an open top 141. A first drain outlet (not shown) is provided near the bottom 143 and is operable to remove solids accumulation from the tank 113. A second drain outlet (not shown) is positioned in one of the side walls 145 and is operable to lower the liquid level in the tank 113. The filter tank 113 further includes an influent chamber 157 defined by the liquid retaining space inside the filter tank 113 that is outside of the filter material 121 and four effluent chambers 153 defined by the spaces within or partially enclosed by the filter material 121. As depicted in FIG. 2, each filter material 121 has a pair of outer surfaces or influent surfaces 159 which face the influent chamber 157, and a pair of parallel spaced apart inner surfaces or effluent surfaces 161 which face the effluent chamber 153.

The filter disks 119 are preferably formed by a plurality of removable filter sectors 171 that are mounted about the hollow drum 125. Each filter sector 171 includes a grid-type frame 173 which supports the filter material 121. Preferably, the filter material

121 is in the form of a bag that is fitted over, and supported by, the grid frame 173. Referring to FIG. 4, the filter material 121 is preferably made of one or more layers of two to six mm thick needled polyester felt. Each layer may be formed by conventional means, for example, by pressing 50 cm thick polyester fabric comprised of very fine fiber particles about 50 microns or less in diameter and then needling the pressed fabric to reorient fiber particles in the vertical or transverse direction. Referring to FIG. 4, a supporting weave 175 is arranged in the middle of the layer. As a result of the needled felt process, the polyester fibers form a multi-layer random web structure lacking in consistent straight-through or transversely disposed pores between adjacent fibers. The needled polyester felt filter material 121 is, therefore, referred to as having an average free (or unencumbered) passage between polyester fibers and through the filter material 121. Preferably, the free passage of the filter material 121 is in the range of about 5 microns to 10 microns, while the space percentage of the solid particles in the filter material 121, including the polyester fiber, amounts to about ten to fifteen percent. Filter disks 119 equipped with suitable filter material 121 having an average free passage or flow through size of 5 microns for use in the present invention is commercially available from Aqua-Aerobic Systems, Inc, of Rockford, Illinois, under the designation 101. Filter disks 119 equipped with suitable filter material 121 having an average free passage or flow through size of 10 microns for use in the present invention is also commercially available from Aqua-Aerobic Systems, Inc., under the designation 102.

A stream of water containing suspended solids aggregates (including microbial contaminants) may be supplied from the agglomeration vessel 33 to the filter tank 113 by gravity feed or by a pump (not shown)

through an influent supply line 163. The water enters the influent chamber 157 and then passes through the filter material 121 of the filter disks 119. As the water stream passes through the filter material 121, the path of suspended solids in the water stream is hindered by polyester fibers in the web structure causing the solids to be caught in between adjacent fibers or to adhere to the fibers themselves. Due to the random web structure of the filter material 121, individual flowlines in the stream carrying the suspended solids will typically deviate from a straight-through path through the filter material 121, thereby increasing the chances of the suspended solids (i.e., the solids aggregates) of being caught within the filter material 121, regardless of the size of the solids.

The filter material 121, as employed in the method of the present invention, is capable of separating or removing pathogenic microorganisms from a volume of waste water more effectively than prior art water filtration techniques. More specifically, the method according to the invention removes greater than about 50% of microbial contaminants, including pathogenic microorganisms, from the volume of water. Preferably, the method removes greater than 90%, more preferably greater than 99%, and most preferably, greater than 99.9% of microbial contaminants, including pathogenic microorganisms, from the volume of water.

In a significant and unexpected aspect of the present invention, the process removes microbial contaminants that are less than about 10 microns in size, and/or microbial contaminants that are less than about 5 microns in size. Preferably, the method removes greater than about 50% of microbial contaminants that are less than about 10 microns and/or less than about 5 microns in size from the volume of water. More preferably, the invention removes greater than about 90%, more preferably greater than about 99%,

and most preferably, greater than about 99.9% of microbial contaminants that are less than about 10 and/or 5 microns in size from the volume of water.

In another significant and unexpected aspect of the invention, the treatment method removes microbial contaminants that are less than about 0.1 microns in size. Preferably, the method according to the invention removes greater than about 50% of microbial contaminants that are less than about 0.1 microns in size from the water. More preferably, the invention removes greater than 90%, and most preferably greater than 99% of microbial contaminants that are less than about 0.1 microns in size from the volume of water.

The volume of water stream may also contain pathogenic microorganisms (e.g., protozoan, bacteria, and viruses) that are less than about 5 microns in size. In such case, the method according to the invention unexpectedly removes greater than about 50%, greater than about 90%, and even greater than 99.9% of such pathogenic microorganisms from the volume of water.

Further, the volume of water may contain a substantial concentration of pathogenic microorganisms less than about 0.1 microns in size, including, but not limited to viruses, and the method according to the invention unexpectedly removes greater than about 50%, greater than about 90%, greater than about 99%, and even greater than 99.9% of such pathogenic microorganisms from the volume of water. In more specific terms, the reference volume of water may contain protozoan pathogens including *Cryptosporidium sp.* and *Giardia sp.*, and the step of passing water through the filter membrane may separate greater than about 50%, more preferably greater than about 90%, and more preferably greater than 99.9% of the *Cryptosporidium sp.* and *Giardia sp.* from the water stream. The reference volume of water may also contain viruses, and the step of passing water through the

filter membrane unexpectedly separates greater than about 50%, more preferably greater than about 90%, and more preferably greater than about 99.9% of the viruses from the reference volume of water.

The reduction or removal rates described above may be achieved using a method preferably employing a needled polyester felt filter material 121 having an average free passage size of 5 microns, or greater than 5 microns (i.e., 10 microns). Moreover, such reduction or removal rates may be achieved using a process wherein the water is passed at least once or a number of times through the filter material 121.

It is common in the art of water treatment to refer to the removal or reduction of microbial populations in terms of log removal rather than in percent removal. The following Table 1 represents a conversion of percent removal into terms of log removal, and gives examples of populations that remain after a certain log removal occurs upon an initial population of microorganisms.

Table 1

Log Removal	Percent Removal	Initial Population of Microorganisms 100	1,000	100,000	1,000,000
1	90	10	100	10,000	100,000
2	99	1	10	1,000	10,000
3	99.9	0.1	1.0	100	1,000
4	99.99	0.01	0.1	10	100
5	99.999	0.001	0.01	1	10
6	99.9999	0.0001	0.001	0.1	1

The use of the present invention to treat water having a significant initial concentration of microbial contaminants preferably results in at least one log reduction in the amount of microbial contaminants in the water. More preferably, a log reduction of 2, and more preferably, a log reduction of 3 is obtained.

Additionally, the use of the present invention also preferably results in at least one log reduction in amount of microbial contaminants that are less than about 5 microns in size, and more preferably a log reduction of at least 2 or 3 is obtained for microbial contaminants that are less than about 5 microns in size. Additionally, the use of the present invention also preferably results in at least one log reduction in amount of microbial contaminants that are less than about 0.1 microns in size, and more preferably, a log reduction of at least 2 is obtained for microbial contaminants that are less than about 0.1 microns in size.

After passing through the filter material 121, the filtered water flows into the effluent chamber 153 and then into hollow drum 125. From the hollow drum 125, the filtered water flows into a rising conduit 167 and out of the filter tank 113 through the effluent outlet 117. The effluent outlet 117 is typically positioned at a level adjacent the uppermost portions of the filter disks 119.

The filter disks 119 may be cleaned periodically of filtered solids and biogrowth on the filter material 121 using either a backwash system or a spray wash system. The backwash system includes a backwash pump 172, suction piping 195 and a plurality of suction heads 177 positioned nearly adjacent the influent surfaces of the filter material. During a backwash operation, the suction heads 177 engage the influent surfaces 159 of the filter material 121 such that the flexible filter material 121 conforms to the suction heads 177 and draw filtered water from the effluent chambers 157 through the filter material 121 in a direction reverse of the normal filtering direction. The resulting backwash stream removes the filtered solids (including microbial contaminants) from the filter material 121 and carries the dislodged solids with backwash water to a discharge conduit (not shown)

for discharge at a location (not shown) external of the filter tank 113. Meanwhile, the filter disks are rotated by energizing motor 137 and driving sprocket 131 through drive chain 133. In this manner, essentially all of the influent surfaces 159 of the filter material 121 is brought into contact with the suction heads 177.

The spray wash system includes a high-pressure pump (not shown) connected to four pairs of spray nozzles or nozzle heads 185. Each nozzle head 185 is positioned nearly adjacent the influent surface 159 of the filter material 121. When actuated, the high-pressure pump delivers a liquid stream at high pressure to each of the nozzle heads 185 and each nozzle head 185 directs a high velocity liquid stream against the influent surface 159 of the filter material 121. The liquid stream acts to wash the influent surface 159 and to remove solids and other fine particles including microbial contaminants that accumulate thereon. The liquid stream also penetrates the influent surface 159 to impact and dislodge filtered solids entrained within the filter material 121. In an alternative arrangement, the nozzle heads 185 can be positioned inside the effluent chambers 157 to direct liquid streams in opposite directions against portions of the effluent surfaces 161.

Other aspects of the filter apparatus 29 and their operation are also discussed in U.S. patents nos. 5,362,401 and 5,374,360, both of which are assigned to the assignee of the present invention. U.S. patent nos. 5,362,401 and 5,374,360 are hereby incorporated by reference.

Before distribution as potable water fit for human consumption, the filtered water is disinfected using a disinfecting agent such as chlorine. In this regard, it is advantageous to remove as much of the suspended solids prior to chlorine treatment since the solids tend to absorb chlorine and, thus, increases the amount

of chlorine required for disinfection. Over-chlorination is not only expensive but may be harmful if chlorine is discharged at high levels.

Referring to FIG. 1, the effluent or filtrate discharged from the filter apparatus 29 is sent to a conventional disinfecting facility 31. Typically, the disinfecting facility 31 will include a chlorination tank 41, wherein chlorine is added to the filtered water. Due to the effectiveness of the filtration process according to the invention, the filtered water contains a minimal concentration of total suspended solids, and therefore does not absorb 25 as much of the chlorine as in prior art treatment methods. Accordingly, the method requires only a minimal amount of chlorine to disinfect a volume of water. After the water is treated in the disinfection system, it is discharged into a potable water holding tank 51 as conventionally known, and/or to a potable water distribution system.

The following examples are intended to exemplify embodiments of the invention and are not to be construed as limitations thereof.

<u>Example</u>

A series of test examples were performed to evaluate the removal of enteric viruses and protozoan parasites from high purity water utilizing a method according to the present invention. A bench scale filter apparatus including a needled polyester felt filter membrane was set up and tested for its ability to remove microbial contaminants from water. The filter apparatus used comprised an elongated tube having upper tube portion and a lower tube portion which were separated by a needled polyester felt filter membrane. The filter membrane was supported by a support ring.

A bench scale filter apparatus as discussed above was set up and connected to a volume of high purity

water. Coliphage MS-2 were grown and assayed in *Escherichia coli* ATCC 15597 by the PFU method and then added to the ultra-pure water to a concentration of approximately 10^7/liter. MS-2 coliphage are of a similar shape and size to poliovirus and have been used in studies to evaluate water and wastewater treatment. Because MS-2 coliphage exhibits poor absorption to surfaces, they are often used to evaluate filtration devices and their use is considered a "worst case" model of virus removal by filtration.

Further, live *Cryptosporidium* oocysts were obtained from infected calves and purified by density gradient centrifugation in sucrose. The purified *Cryptosporidium sp.* oocysts were then added to the ultra-pure water before filtration or addition of the floc producing substance.

A series of four tests were run using this system. In the first series of tests, Filter Type 101 having a 5 micron flow through or free passage size was used on the filter apparatus, and no filter aid agents were used. In the second series of tests, Filter Type 101 was again used, but filter-aid agents (FAA) including an alum coagulation agent was added to the wastewater at a concentration of about 10 ppm, for a contact time of about 2 minutes. Then, an organic polymer flocculant was added to the wastewater at a concentration of about 1 ppm for a contact time of about 1 minute.

In the third series of tests, Filter Type 102 having a 10 micron flow through or free passage size was used on the filter apparatus, and no filter-aid agents were used. In the fourth series of tests, Filter Type 102 was used, and filter aid agents including an alum coagulation agent was added to the wastewater at a concentration of about 10 ppm, for a contact time of about 2 minutes. Then, an organic polymer flocculant was added to the wastewater at a

concentration of about 1 ppm for a contact time of about 1 minute.

In each series of test runs 10 ml samples for coliphage analyses were collected before and after filtration and compared to determine removal of the viruses by the filter system. Removal of *Giardia* cysts and *Cryptosporidium* oocysts was determined by direct assay of the wastewater before and after filtration. One liter samples before and after filtration were collected and centrifuged for 10 minutes at 1,400 X g to pellet the cysts and oocysts. The organisms were resuspended in 10 ml of distilled water containing 0.1% Tween 80. The organisms were then passed through membrane filters and stained with fluorescent labeled monoclonal antibodies and examined under a UV light microscope as described in the *Manual of Environmental Microbiology* for the presence of oocysts and cysts.

The following tables illustrate the results of the series of testing, indicating the performance of the current invention to remove microbial contaminants from water. The Filter Type column indicates the type of filter material used, wherein 101 indicates a filter material on a filter disk(s) commercially available from Aqua-Aerobic Systems, Inc. (discussed previously) and 102 indicates a filter disk(s) also commercially available from Aqua-Aerobic Systems, Inc. (also discussed previously). The Filter Type column also indicates whether a filter aid agent (FAA) was used wherein "with FAA" indicates the use of a filter aid agent, and "no FAA" indicates that no filter aid agent was used. The remaining columns indicate the influent and effluent concentration of the relevant microbial contaminant being measured, and the percent reduction obtained.

Cryptosporidium Reduction by the Filter
Results are given as oocysts / mL

Filter Type	Influent	Effluent	Percent Reduction
101 With FAA	9.60×10^3	5.6	>99.9
101 No FAA	4.01×10^4	4.60×10^4	No Reduction
102 With FAA	8.84×10^3	8.3	>99.9
102 No FAA	4.01×10^4	4.24×10^4	No Reduction

MS-2 Reduction by Aqua-Aerobic Filter
Results are given as PFU/mL

Water

Filter Type	Influent	Effluent	Percent Reduction
101 With FAA	2.10×10^6	2.65×10^2	99.88
101 No FAA	2.10×10^6	1.06×10^6	49.52
102 With FAA	1.61×10^6	1.75×10^2	99.89
102 No FAA	2.30×10^6	9.94×10^5	56.78

While some embodiments of the invention are shown in the drawings and discussed above, alternate embodiments will be apparent to those skilled in the art and are within the intended scope of the present invention. Therefore, the invention is to be limited only by the following claims.

What is Claimed is:

1. In a process for treating water to produce potable water fit for human consumption, a method for reducing the concentration of pathogenic microorganisms suspended in water, the method comprising the steps of:

providing a volume of influent water that contains suspended pathogenic microorganisms;

promoting the agglomeration of suspended solids in the volume of influent water to form suspended solids aggregates, the solids aggregates including pathogenic microorganisms;

providing a filter membrane made of cloth material; and

passing the volume of influent water including the solids aggregates through the filter membrane to separate pathogenic microorganisms from the volume of influent water.

2. The method of claim 1, wherein the step of passing the volume of influent water through the filter material separates greater than about 50% of the pathogenic microorganisms from the volume of influent water.

3. The method of claim 1, wherein the step of passing the volume of influent water through the filter material separates greater than about 99% of the pathogenic microorganisms from the volume of influent water.

4. The process of claim 1, wherein the step of passing the volume of influent water through the filter material separates greater than about 99.9% of the pathogenic microorganisms from the volume of influent water.

5. The method of claim 1, wherein the volume of influent water contains pathogenic microorganisms less than about 10 microns in size; and

wherein the step of passing the volume of influent water through the filter membrane separates greater than about 50% of the pathogenic microorganisms less than about 10 microns from the volume of influent water.

6. The method of claim 5, wherein the step of passing the volume of influent water through the filter membrane separates greater than about 99.9% of the pathogenic microorganisms less than about 10 microns from the volume of influent water.

7. The method of claim 1, wherein the volume of influent water contains pathogenic microorganisms less than about 5 microns in size; and

wherein the step of passing the volume of influent water through the filter membrane separates greater than about 50% of the pathogenic microorganisms less than about 5 microns from the volume of influent water.

8. The method of claim 7, wherein the step of passing the volume of influent water through the filter membrane separates greater than about 99.9% of the pathogenic microorganisms less than about 5 microns from the volume of influent water.

9. The method of claim 1, wherein the volume of influent water contains pathogenic microorganisms less than about 0.1 microns in size; and

wherein the step of passing the volume of influent water through the filter membrane separates greater than about 50% of the pathogenic microorganisms less than about 0.1 microns from the volume of influent water.

10. The method of claim 9, wherein the step of passing the volume of influent water through the filter membrane separates greater than about 99% of the pathogenic microorganisms less than about 0.1 microns from the volume of influent water.

11. The method of claim 1, wherein the volume of influent water contains protozoan pathogens including *Cryptosporidium* and *Giardia*; and

wherein the step of passing the volume of influent water through the filter membrane separates greater than about 50% of the *Cryptosporidium* and *Giardia* from the volume of influent water.

12. The method of claim 11, wherein the step of passing the volume of influent water through the filter membrane separates greater than about 99.9% of the *Cryptosporidium* and *Giardia* from the volume of influent water.

13. The method of claim 1, wherein the filter membrane is constructed of random web needled polyester felt.

14. The method of claim 13, wherein the filter membrane is characterized by an average free passage size through the filter membrane of greater than about 5 microns.

15. The method of claim 1, wherein the promoting step includes adding an agglomerate-promoting agent to the volume of influent water.

16. The method of claim 15, wherein the step of adding an agglomerate-promoting agent includes adding a coagulant.

17. The method of claim 16, wherein the agglomerate-promoting agent includes alum.

18. The method of claim 1, wherein the promoting step includes:

adding a coagulant to the volume of influent water; and

adding a flocculant to the volume of influent water.

19. The method of claim 18, wherein the flocculant is an organic polyelectrolyte.

20. A process for treating water to produce potable water fit for human consumption, the treatment process comprising the steps of:

providing a volume of water containing suspended pathogenic microorganisms;

adding an agglomeration-promoting agent to the volume of water to form solids aggregates, the solids aggregates including pathogenic microorganisms; providing a filter membrane made of cloth material; passing the volume of water through the filter membrane to separate pathogenic microorganisms from the volume of water; and

disinfecting the volume of water passed through the filter membrane.

21. The process of claim 20, wherein the step of passing the volume of water separates greater than about 50% of the pathogenic microorganisms from the volume of water.

22. The process of claim 20, wherein the step of passing the volume of water separates greater than about 99% of the pathogenic microorganisms from the volume of water.

23. The process of claim 20, wherein the step of passing the volume of water separates greater than about 99.9% of the pathogenic microorganisms from the volume of water.

24. The process of claim 20, wherein the volume of water contains pathogenic microorganisms less than about 10 microns in size; and

wherein the step of passing the volume of water separates greater than about 50% of the pathogenic microorganisms less than about 10 microns from the volume of water.

25. The process of claim 24, wherein the step of passing the volume of water through the filter membrane separates greater than about 99.9% of the pathogenic microorganisms less than about 10 microns from the volume of water.

26. The process of claim 20, wherein the volume of water contains pathogenic microorganisms less than about 5 microns in size; and

wherein the step of passing the volume of water separates greater than about 50% of the pathogenic microorganisms less than about 5 microns from the volume of water.

27. The process of claim 26, wherein the step of passing the volume of water separates greater than about 99.9% of the pathogenic microorganisms less than 5 microns from the volume of water.

28. The process of claim 20, wherein the volume of water contains pathogenic microorganisms less than 0.1 microns in size; and

wherein the step of passing the volume of water separates greater than about 50% of the pathogenic microorganisms less than 0.1 microns in size from the volume of water.

29. The process of claim 20, wherein the volume of water contains pathogenic microorganisms less than 0.1 microns in size; and

wherein the step of passing the volume of water separates greater than about 99% of the pathogenic microorganisms less than 0.1 microns in size from the volume of water.

30. The process of claim 20, wherein the volume of water contains protozoan pathogens including cryptosporidium and giardia; and

wherein the step of passing the volume of water separates greater than about 50% of the *Cryptosporidium* and *Giardia* from the volume of water.

31. The process of claim 30, wherein the step of passing water through the filter membrane separates greater than about 99.9% of the *Cryptosporidium* and *Giardia* from the volume of water.

32. The process of claim 20, wherein the filter membrane is constructed of random web needled polyester felt.

33. The process of claim 32, wherein the filter membrane is characterized by an average free passage size through the filter membrane of greater than about 5 microns.

34. The process of claim 20, wherein the step of adding an agglomerate-promoting agent includes adding a coagulant to the volume of water.

35. The process of claim 34, wherein the coagulant is selected from the group: aluminum salts, iron salts, activated silica, bentonite, sodium chloride, cationic polyelectrolytes, and mixtures thereof.

36. The process of claim 35, wherein the step of adding an agglomerate-promoting agent includes adding a flocculant to the volume of water.

37. The process of claim 35, wherein the flocculant is selected from the group: aluminum sulfate, lime, iron salts, polyelectrolytes, anionic polymers, and a mixture thereof.

38. The process of claim 20, wherein the step of disinfecting includes adding chlorine to the volume of water.

39. In a process for treating water to produce potable water fit for human consumption, a method for reducing the concentration of pathogenic microorganisms suspended in a volume of water, the method comprising the steps of:

providing a volume of influent water that contains pathogenic microorganisms less than about 10 microns in size;

adding an agglomeration-promoting agent to the volume of water to form suspended solids aggregates in the volume of influent water, the solids aggregates including pathogenic microorganisms;

providing a filter membrane; and

passing the volume of water through the filter membrane to separate greater than about 50% of the pathogenic microorganisms less than about 10 microns in size from the volume of water.

40. The method of claim 39, wherein the step of passing the volume of water through the filter membrane separates greater than about 99% of the pathogenic microorganisms less than about 10 microns from the volume of water.

41. The method of claim 39, wherein the step of passing the volume of water through the filter membrane separates greater than about 99.9% of the pathogenic microorganism less than about 10 microns from the volume of water.

42. The method of claim 39, wherein the volume of water contains pathogenic microorganisms less than 0.1 microns in size; and

wherein the step of passing the volume of water through the filter material separates greater than about 50.0% of the pathogenic microorganisms less than 0.1 microns from the volume of water.

43. The method of claim 42, wherein the step of passing the volume of water through the filter membrane separates greater than about 99% of the pathogenic microorganisms less than 0.1 microns from the volume of water.

44. The method of claim 39, wherein the volume of water contains protozoan pathogens including *Cryptosporidium* and *Giardia*; and

wherein the step of passing the volume of water through the filter membrane separates greater than about 50% of the *Cryptosporidium* and *Giardia* from the volume of influent water.

45. The method of claim 44, wherein the step of passing the volume of water through the filter membrane separates greater than about 99.9% of the *Cryptosporidium* and *Giardia* from the volume of water.

46. The method of claim 39, wherein the filter membrane is constructed of a cloth material.

47. The method of claim 46, wherein the filter material is constructed of a random web needled polyester felt.

48. The method of claim 47, wherein the filter membrane is characterized by an average free passage size through the filter membrane of greater than about 5 microns.

49. The method of claim 48, wherein the step of passing the volume of water through the filter membrane separates greater than about 99% of the pathogenic microorganism less than 5 microns in size from the volume of water.

50. The method of claim 39, wherein the step of adding an agglomerate-promoting agent includes adding a coagulant to the volume of water.

51. The method of claim 50, wherein the coagulant is selected from the group: aluminum salts, iron salts, activated silica, bentonite, sodium chloride, cationic polyelectrolytes, and mixtures thereof.

52. The method of claim 51, wherein the step of adding an agglomerate-promoting agent includes adding a flocculant to the volume of influent water.

53. The method of claim 52, wherein the flocculant is selected from the group: aluminum sulfate, lime, iron salts, polyelectrolytes, non-ionic polymers, and a mixture thereof.

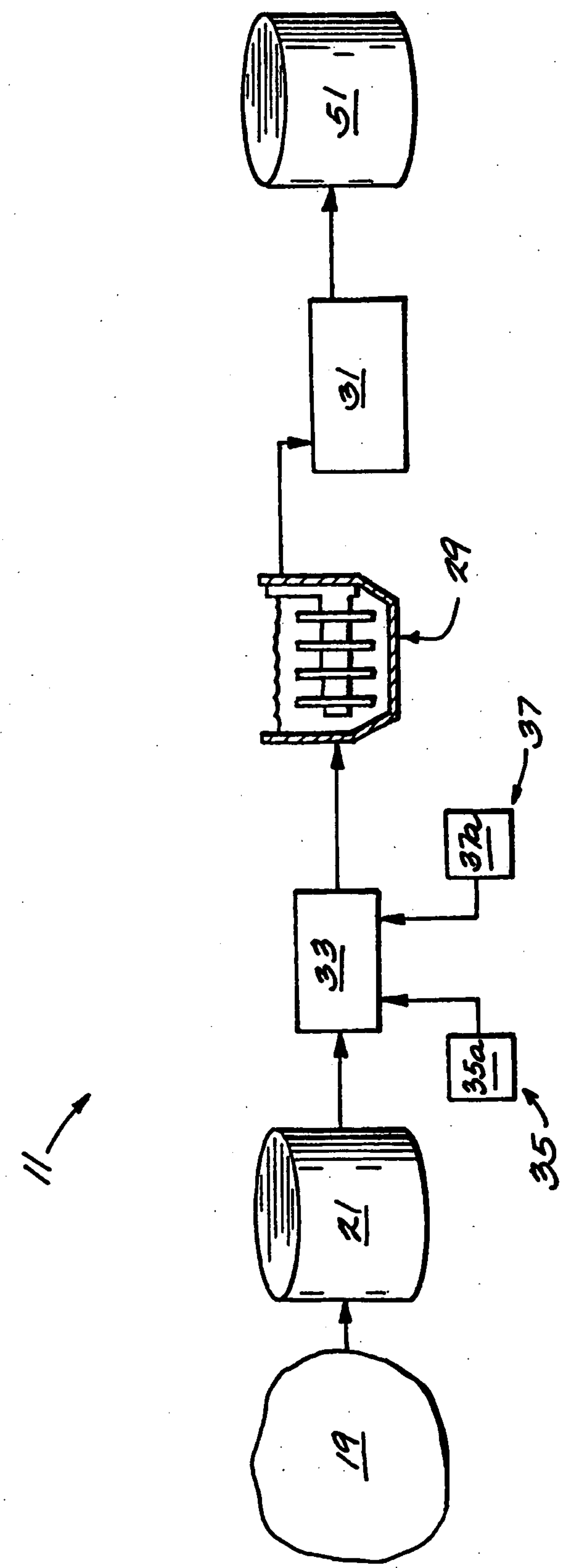

Fig. 1

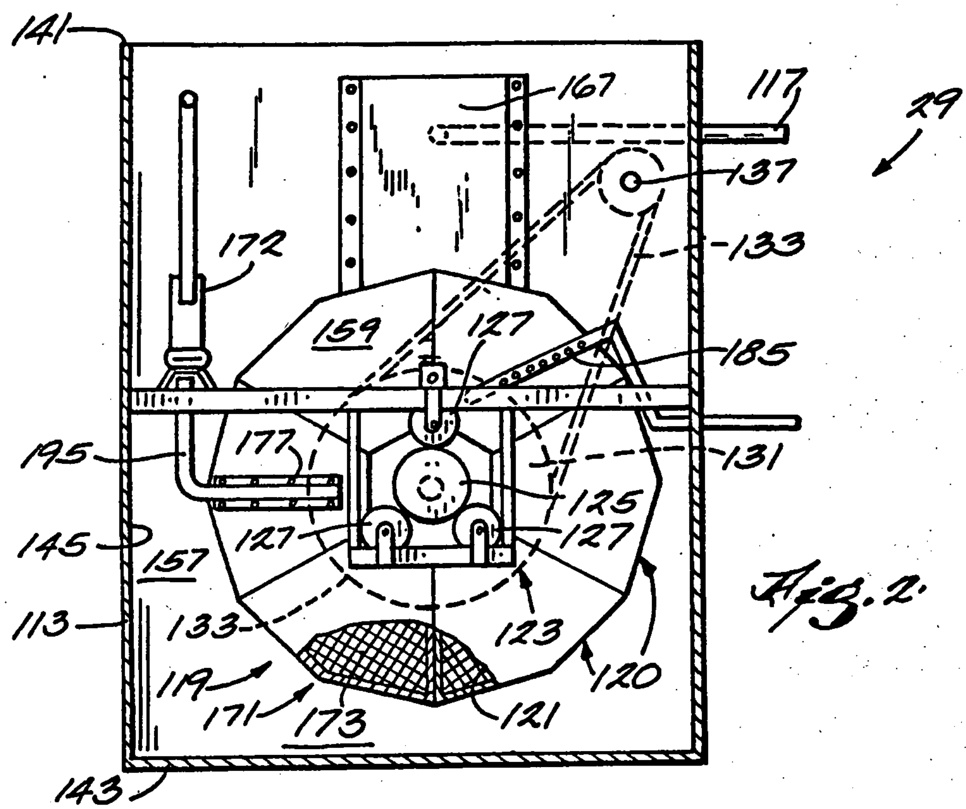
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Fig. 2.

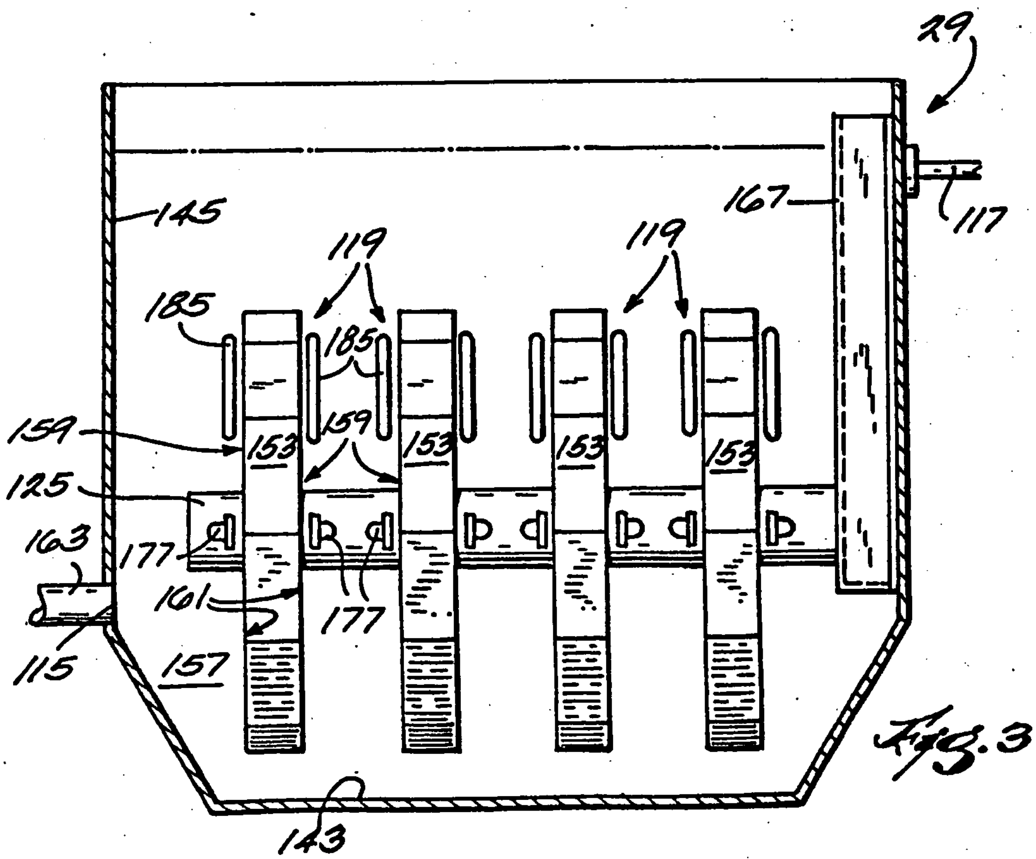
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Fig. 3

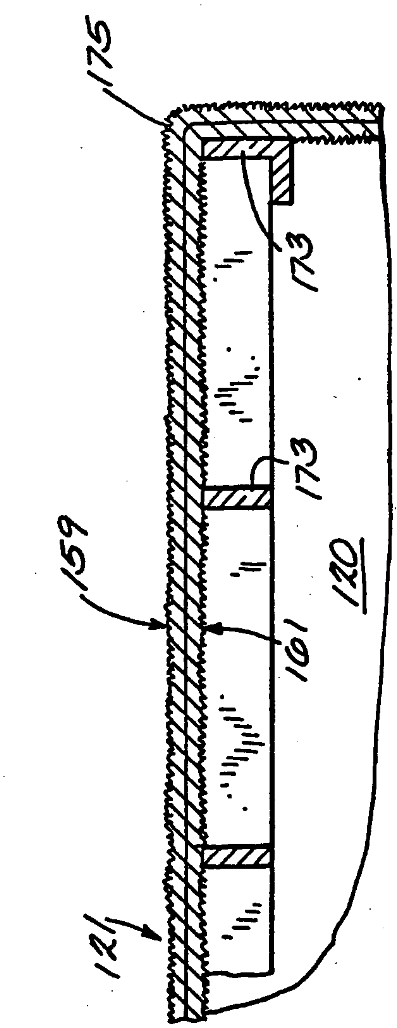

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/14768

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :C02F 1/52
US CL :210/728, 754, 764
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 210/638, 639, 702, 725, 727, 728, 754, 764

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, Derwent
search items: needlefelt, microorganisms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,543,056 A (MURCOTT et al.) 06 August 1996, abstract, col. 1, lines 23-31, col. 3, lines 50-56, col. 4, lines 36-60, col. 6, lines 32-38, col. 15, lines 13-42	1-53
Y	Aqua-Aerobic Systems, Inc., AquaDisk Filter Cloth-Media Filters Brochure, Bulletin #600A, April 1996, p. 1	1-53
Y	US 5,456,836 A (JEFFERY et al.) 10 October 1995, col. 7, lines 37-55	13, 14, 20-38, 47, 48
Y	Mecana Umwelttachnik AG, Mecana Disk Filter Description, September 1991, section 3	14, 48
Y	FR 1,594,088 A (LESERRE) 10 July 1970, abstract	20-38

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 AUGUST 1999	14 SEP 1999

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/14768

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,173,532 A (KEOTEKLIAN) 06 November 1979, abstract, claim 14	1-53